

Using Proteins to Build Nanocomputers

- **Basic building blocks of life may be harnessed to build computers and sensors on the nanoscale**
- **Proteins provide self-assembling structures that can be engineered to build ordered arrays of quantum dots**

How low can we go? This is the question challenging scientists who want to build ever-smaller electronic components. As famed physicist Richard Feynman said in 1959, “there is plenty of room at the bottom,” meaning at the atomic or nanometric scale, but even Feynman could only guess at how we might eventually build things “down there.” As current lithographic techniques for etching semiconductor circuits rapidly approach their physical limits, scientists are looking for new and less expensive ways to fabricate circuits at infinitesimally small scales. NASA scientists have discovered a new tool that may help accomplish this goal—proteins.

Jonathan Trent and his team of researchers at NASA Ames Research Center have genetically engineered proteins, known as “heat shock proteins or HSP60s,” to take advantage of their self-assembling capability and to fabricate ordered arrays of metal or semiconductor quantum dots (QDs).

Trent’s research team is funded by the CICT Program’s Information Technology Strategic Research (ITSR) Project, which investigates, develops, and evaluates a broad portfolio of fundamental information technologies, including biologically inspired nanotechnology, for infusion into NASA missions.

Fat fingers can’t touch this

Nanotechnology is the creation of functional materials, devices, and systems by controlling matter at the atomic or molecular level—from 1 to 100 nanometers in size. Nanotechnology also exploits the “quantum effects” which, operating only at the nanoscale, can fundamentally change the properties (chemical, physical, and biological) traditionally associated with larger-scale devices.

A nanometer is one billionth of a meter—a scale where atoms are countable. To understand how small this is, consider that the average human hair is 100,000 nanometers wide. When you want to create electronic or photonic devices from materials that are this small, you soon find that your “fat fingers” are of no help. Where do you find the tools for building such incredibly tiny devices?

Until now, engineers have used lithographic patterning processes of progressively

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Technology Spotlight

Technology

Genetically engineered chaperonin “heat shock” proteins

Function

Provide self-assembling structure for creating nanoscale electronic circuit arrays and photonic sensors

Relevant Missions

- Exploration Systems Enterprise missions
- Biological and Physical Research Enterprise missions
- Aeronautics Enterprise missions
- Space Science Enterprise missions

Applications

- Nanoscale electronic devices
- Nanoscale photonic devices

Features

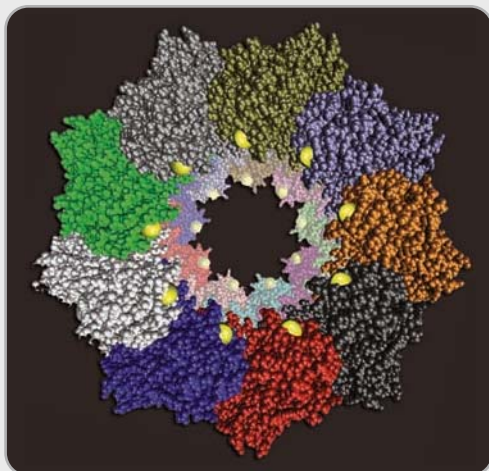
- Proteins found almost everywhere
- Extremely resistant to heat
- Malleable via genetic manipulation
- Self-assemble in nanoscale ordered arrays

Benefits

- Provide inexpensive structure for supporting and arranging quantum dots
- Enable fabrication of logic and sensor arrays at the nanoscale

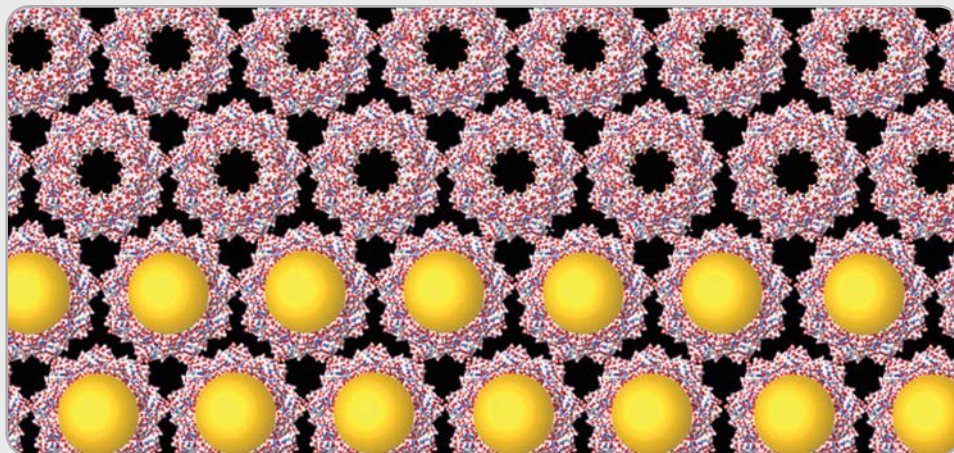
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This computer model shows the chaperonin protein with a genetically engineered hole for inserting quantum dots of metals and semiconductors.

(Graphic: Andrew McMillan, NASA)



This computer model shows nanoscale arrays self-assembled by chaperonin proteins. The lower rows show quantum dots of gold inserted in the protein holes.
(Graphic: Andrew McMillan, NASA)

smaller sizes and greater integration densities. At scales below 100 nanometers, however, even ion and electron beam lithography become time consuming, tedious, and prohibitively expensive.

A self-assembling template

To solve the problem of fabricating logic and sensor arrays at the nanoscale, and to do it inexpensively, Trent and his colleagues combined their knowledge of the “soft” biological sciences and the “hard” materials sciences. By genetically engineering proteins that self-assemble into regular arrays so that they also bind soft-metals and semiconductor quantum dots (QDs), Trent and his team demonstrated that these proteins could maneuver and organize QDs. QDs are nanoparticles of metal or semiconductor material that have quantum properties. If they can be arranged and manipulated, they may provide the basis for future generations of electronic and photonic devices. These devices would take advantage of their quantum effects to store and process unprecedented amounts of information at very high speeds.

Chaperonin can take the heat

Trent, an astrobiologist, has been studying the most extreme environments on Earth to learn the biological “tricks” that organisms use to survive in these environments. He found the HSP60 heat-shock protein in a microbe, called *Sulfolobus shibatae*, that thrives in near-boiling acidic mud pools.

“All organisms—from bacteria to plants to humans—make heat shock proteins when they become overheated,” says Trent. “Maybe not surprisingly, *Sulfolobus* makes a

lot of these proteins, and we’ve been studying it to try to understand how these proteins protect us from the heat.” In the process of trying to understand how they work, Trent’s team discovered that these proteins spontaneously form rings, called “chaperonins,” and other interesting structures.

By modifying the gene for the heat-shock protein from *Sulfolobus*, Andrew McMillan and Chad Paavola, fellow researchers on Trent’s team, altered the protein so that it would bind quantum dots. Andrew McMillan, lead author of the team’s research paper published in *Nature Materials*, explains: “What is novel in our work is that we designed this protein so that when it self-assembles into a two-dimensional lattice we can use it as a template to organize metal and semiconductor particles. These structures rival the precise, regular arrays of metals and semiconductors that the electronics industry uses today on a larger scale.”

What’s next?

“There are two approaches that we are now taking to move this research forward,” says McMillan. “One is to incorporate different functionality into the proteins, so they accommodate additional types of metal or semiconductor nanoparticles. The other is to fine-tune the properties of the arrays by controlling nanoparticle sizing, spacing and composition, as well as the interaction of the nanoparticles themselves.”

“Our goal,” adds Trent, “is to demonstrate the feasibility of using proteins as tools for manipulating nanoscale materials of interest in electronics in general and computers in particular. Proteins are the building blocks

for structures as complex and elaborate as humans; the challenge is to see if these same proteins can be harnessed to build functional nanoscale electronic devices that advance the exploration of space and improve our lives on Earth.”

—Larry Laufenberg

For more information or stories online, see www.cict.nasa.gov/infusion

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